PATENT SPECIFICATION

DRAWINGS ATTACHED

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Int. Cl.:—**B** 23 d//B 29 d, f

COMPLETE SPECIFICATION

Apparatus and Method for Reshaping Tubular Bodies

We CONTINENTAL CAN COMPANY, INC., a Corporation of the State of New York, United States of America, of 633, Third Avenue, New York, 17, New York, United States of America, assignee of CURTIS EUGENE MAIER, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the manufacture of hollow articles and more particularly to a method of reshaping tubular bodies and the apparatus for accomplishing such reshaping.

Hollow articles are readily produced in quantity when the shapes of such articles are regular. This is particularly true when the articles are of constant cross section or tapered. However, when the cross section of an arrticle is varied or the surface of the article is specifically configurated, such as by embossing, the forming operation becomes very expensive and heretofore has not been feasible for production in large quantities. The present invention is particularly useful when regularly shaped bodies of ductile material are first formed by relatively inexpensive conventional forming operations, and thereafter, the regularly shaped bodies are reshaped by an explosive forming operation which also may be carried out at a relatively low cost.

This invention has a primary application with respect to articles formed of ductile metals, particularly those made from steel, both coated and uncoated including metal coated steel, such as tin coated steel, aluminum, and the like. However, the invention is not restricted to the shaping of ductile metal articles in that the invention may equally as well be applied to intricately-shaped plastic articles of which the plastic material is of the ductile type. Although polyethylene has proven to be the most desirable plastic at the present, other types of plastics could be utilized, including polyvinyl chloride, polypropylene, polycarbonates, and the like.

Tubular bodies which may be reshaped by the method of the invention generally fall into three categories as follows: (1) tubular bodies open at opposite ends; (2) tubular bodies each having one end only thereof closed either by an integral end closure or a separate end closure attached by any means including welding and crimping; and (3) tubular bodies having end closures at opposite ends thereof with one of the end closures being either integral or attached by any means including welding and crimping and the other end closure being attached by any means including welding and crimping, but with one of the end closures having a large enough hole to permit filling the body with an explosive mixture and the insertion of igniting means. When a tubular body is provided with one or more end closures at the time of the explosive reshaping thereof it is also possible to reshape the end closure.

The invention is readily adaptable to numerous types of articles, but finds particular advantages in the field of containers which are mass produced in regular shapes and wherein the cost of producing irregularly shaped containers is too prohibited to be considered except when conventionally blow molded, such as glass and plastic containers, and even these containers are too expensive to produce in comparison with the manufacturing costs of other containers, such as drums, pails, cans, and the like. On the other hand, the trend in the packaging field has been towards eye appealing containers for facilitating the sales of products, and this invention enables containers of commonly used sizes, including commercially used drums, for

example 55 gallon drums, to be reshaped from existing and newly devised regular shapes to be of the desired configuration.

Metal cans up to one gallon in capacity are at the present time produced at a minimum cost on existing high speed fully automatic can making equipment at the rate of 200 to over 1000 cans per minute. However, to so produce these metal cans, the shape of the side walls of the can bodies is relatively straight-sided, simple, cylindrical, square or oblong, although it is possible for the can bodies to be tapered, and in a separate unit operation, the top and bottom end closures must be manufactured and attached to the previously made can side walls, one end before, and the other end after the product for which the can was manufactured is filled into the can. Cans produced by such a method have the side walls joined at a side seam, which for the majority of products that are to be contained, must be secured by welding, by soldering, or by applying organic sealing cements tailored to the particular product, the strength of which side seam joints decrease rapidly in the order mentioned.

Metal cans are also produced with integral bottoms, and without a side seam joint, by a single or multiple drawing or by extrusion methods, but at slower speeds, the speed being approximately 100 cans per minute. These cans are also formed at a greater cost than the customary three-piece round, square or rectangular cans made by the high speed, fully, automatic method.

On the other hand, glass and conventionally molded plastic containers, while produced at much lower speeds than the three-piece metal cans made on the high speed, fully automatic equipment, may have practically any shape that the customer desires.

The present invention comprises method of reshaping a tubular body wherein the body is enclosed within a shaped mould and its ends are sealed and wherein combustible and combustion supporting gases are introduced into the interior of the body to form an explosive gas mixture therewithin and the mixture is ignited and exploded to produce a gaseous pressure shock wave within the tubular body which outwardly expands the tubular body into conformity with the shape of the mould.

According to another aspect of the invention, apparatus for reshaping tubular bodies comprises a support member, a clamp plate member co-operable with said support for clamping a tubular body to be reshaped therebetween with the ends thereof sealed, a split mould co-operating with said support and said clamp plate for enclosing the tubular body a gas line connected to one of said members, a valve connected to said gas line, other lines connected to said valve for selective communication with said gas line by said valve for the introduction of combustible and combustion supporting gases into the interior of the tubular body to form an explosive mixture therein and an ignition device carried by one of said members for igniting and exploding said gaseous mixture.

The invention will be further described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic view with parts broken away and shown in section, showing the general details of the apparatus for removing a can body from a conveyed line of can bodies and effecting the reshaping of the can body by the method of the invention;

Figure 2 is a fragmentary elevational view showing a portion of the apparatus of Figure 1, with the can body being initially engaged by a centering support therefor;

Figure 3 is a fragmentary schematic elevational view showing a portion of the apparatus of Figure 1 with the can body entering into the mould of the apparatus;

Figure 4 is a fragmentary vertical sectional view showing the can body fully seated and locked within the mold and air within the can body being withdrawn therefrom;

Figure 5 is a schematic view showing the introduction of a combustible gas into the can body;

Figure 6 is a view similar to Figure 5 and shows the introduction of oxygen into the can body;

Figure 7 is a schematic view showing the igniting of the combustible gas and oxygen mixture;

Figure 8 is a schematic elevational view similar to Figure 1 and shows the mold in its open position and the reshaped can body being lowered out of the mold;

Figure 9 is a fragmentary vertical sectional view showing a modified form of support for supporting and centering can bodies having end closures on the lower ends thereof;

Figure 10 is a chart showing the maximum theoretical explosive pressure of various fuels with oxygen and air at different charging pressures;

Figure 11 is a chart showing the theoretical maximum explosive pressure for methane and various oxygen and air to fuel ratios;

Figure 12 is a chart showing the maximum rate of pressure rise of different fuels combined with oxygen for different pressure charging;

Figure 13 is a chart showing the maximum rate of pressure rise of different fuels mixed with air for different charging pressures;

Figure 14 is a perspective view of a container body formed by the method in accordance with the invention starting with a cylindrical body;

Figure 15 is a fragmentary vertical sec-

tional view taken along the line 15—15 of Figure 14 and shows the specific shape of the container body of Figure 14 and the embossing thereof;

Figure 16 is a perspective view of a container formed by the method in accordance with the invention starting with a rectangular cross sectional body;

Figure 17 is a fragmentary vertical sectional view taken along the line 17—17 of Figure 16 and shows the specific shape of the container of Figure 16 and the embossing thereof and

Figure 18 is a fragmentary vertical sectional view similar to Figure 17 and through only an upper part of a slightly modified container wherein the embossing has been replacing by debossing.

Referring now to the drawings in detail, Figures 1 to 8 show schematically a step-by-step operation of reshaping a container body by the method in accordance with this invention. Although hereinafter reference will be made to the reshaping of a can, it is to be understood that various types of tubular bodies may be shaped and the invention is in no way restricted to cans. Referring firstly to Figure 1, can bodies 16 are moved along a support 15 with the can bodies 16 being disposed in spaced relation. It is preferable that the can bodies 16 be delivered along the support 15 in a step-by-step manner in order to provide the necessary time for the reshaping operation, although if desired, the can bodies 16 could be continuously supplied and means could be provided for presenting a single can body to the reshaping mechanism upon demand.

The support 15 is provided with a mounting block 17 in which there is seated a support member 18 adapted to be vertically lifted out of the mounting block 17. In addition to being seated within the mounting block 17, the support member 18 is carried by a vertically reciprocating plunger 19 for movement therewith. The plunger 19 has an upper end closure 20 and is provided adjacent the upper end thereof with an outwardly directed flange 21. The support member 18 is provided with an internal recess 22 in which the flange 21 is received. The recess 22 has a greater vertical extent than the flange 21 so that upon initial upward movement of the plunger 19, there will be no movement of the support member 18 so that the upper end of the plunger 19 may enter into a can body 16 to assure the supporting and alignment of the can body 16 with the support member 18. After a slight initial upward movement of the plunger 19, the flange 21 engages the portion of the support member 18 defining the upper end of the recess 22 and the support member 18 is moved upwardly together with the plunger 19. At this time, it is pointed out that the plunger 19 may be moved upwardly in any desired manner, including the plunger 19 being part of a fluid motor.

Another support 23, which has been schematically illustrated, overlies the support 15 and carries a clamp plate 24 which is disposed in alignment with the support member 18. The clamp plate 24 has a depending central portion 25 which serves to guide the upper end of a can body 16 to assure the proper alignment of the can body 16 with the clamp plate 24. The underside of the clamp plate 24 surrounding the depending central portion 25 is provided with a suitable sealing ring 26 which is engageable with the upper end of the can body 16 to effect the sealed closing of the can body 16. The support member 18 has a similar sealing ring 27 on the upper surface thereof for engaging and sealing the lower end of the can body 16.

The clamp plate 24 is provided with a suitable igniter 28 which may be in the form of a spark plug or any other suitable type of igniter. The igniter 28 is provided with suitable spaced posts 29 which are preferably positioned so as to be disposed centrally of the can body 16 when the can body 16 is engaged with the clamp plate 24.

The clamp plate 24 is also provided with a pipe 30 which extends through the clamp plate 24 and is suitably screw-threaded therein at 31. The pipe 30 is used for exhausting a can body and supplying the necessary materials of combustion thereto in the performance of a reshaping operation.

The support 23 has a pair of depending brackets 32 of which only one is shown. Each depending bracket 32 carries a fluid motor 33 of the double acting type with each fluid motor 33 including an extensible plunger 34 which, in turn, supports a mold half 35. The two mold halves 35 are preferably identical, and the mold halves 35 are provided with internal configurations 36 corresponding to the desired final shape of a can body.

The pipe 30 leads to a rotary valve assembly, generally referred to by the numeral 37. The valve assembly 37 includes a housing 38 and a rotatable valve member 39. The valve member 39 is only schematically illustrated, but it is to be understood to have a fixed port 40 which is continuously aligned with the pipe 30. The valve member 39 also has a rotatable port 41 which is in continuous communication with the port 40.

In addition to the pipe 30 secured to the valve housing 38, there is a pipe 42 which is secured to a suitable vacuum source and will be considered a vacuum line. A pipe 43 is connected to the housing 38 for applying a combustible gas under pressure to the valve 37. A pipe 44 is secured to the housing for delivering to the valve 37 an oxidizing agent,

such as air or oxygen under pressure. A further pipe 45 is connected to the atmosphere. It is to be noted that the pipes 30, 42, 43, 44 and 45 are equally spaced about the circumference of the valve housing 38 with the exception that there is a station skipped between the pipes 44 and 45, there being no pipe in diametrically opposite relation with respect to the pipe 42. A suitable spark control device is associated with the valve 37 and when the valve 37 is positioned at the station between the pipes 44 and 45, the spark device will serve to energize the igniter 28 for a purpose to be described hereinafter. Although the valve 37 may be continuously rotated, it is preferred that the rotation of the valve 37 be on a step-by-step basis in order to provide sufficient time for the flow of gases through the various pipes.

Referring now to Figure 2 in particular, it will be seen that after a can body 16 has been aligned generally with the support member 18, the initial upward movement of the plunger 19 will result in the upper end of the plunger 19 entering into the lower end of the associated can body 16 and the centering of the can body 16 with respect to the support member 18.

Referrring now to Figure 3, it will be seen that as the plunger 19 continues its upward movement, the flange 21 will serve to lift the support member 18 and that the support member 18 will engage the lower end of the can body 16. The can body 16 is illustrated in Figure 3 as being moved between the spaced apart mold halves 35. At this time, the valve 37 is in its EXHAUST position.

The continued upward movement of the plunger 19 results in the upper end of the can body 16 engaging the sealing ring 26 of the clamp plate 24. In the event there should be any slight misalignment of the can body 16 with respect o the clamp plate 24, the downwardly projecting portion 25 of the clamp plate 24 will automatically realign the can body 16. After the can body 16 has been tightly clamped against the underside of the clamp plate 24 so that the upper and lower ends of the can body 16 are sealed, the mold halves 35 are moved together about the can body 16 to provide a continuous mold about the can body 16. It is to be understood that the termination of the upward movement of the plunger 19 and the closing of the mold halves 35 will be effected by automatic mechanism which may be of any conventional type, including a trip lever actuated by the plunger 19, and the details of such mechanism are not an essential feature of this invention.

After the ends of the can body 16 have been sealed and the mold halves 35 moved to their closed positions, the valve member 37 is moved to its VACUUM position wherein a vacuum is drawn through the pipe 30 so as to remove a major portion of the air trapped within the can body 16. After the removal of this excess air has been accomplished, the valve 37 is rotated to its COMBUSTIBLE GAS position wherein a combustible gas under pressure is delivered to the interior of the can body 16 through the pipe 30. This is best shown in Figure 5.

Referring now to Figure 6, it will be seen that the valve 37 has the valve member 39 thereof rotated to the OXYGEN position. Although it has been indicated that oxygen will be delivered to the valve 37 through the pipe 44, it is to be understood that any type of oxidizing agent may be delivered to the valve 37 through the pipe 44 and that in many instances in lieu of using oxygen, air will be delivered to the valve 37 through the pipe 44. The compressed air, oxygen or other oxidizing agent is delivered into the interior of the sealed can body 16 to mix with the combustible gas already delivered to the interior of the can body 16.

Reference is now made to Figure 7, wherein the igniter 28 is illustrated in the act of igniting and exploding the combustible gas mixture disposed within the can body 16. When the combustible gas mixture explodes, there will be a rapid increase in pressure within the can body 16, and while the extremely high pressure within the can body 16 has a tendency to deform the can body 16 outwardly to conform to the shape of the mold halves 35, it has been found that the shock wave caused by the high burning rate is the primary cause of the shaping of the metal through its plastic range to a very much greater elongation than would be possible by more slowly applied forces.

Referring now to Figure 8, it will be seen that the plunger 19 is in the process of moving downwardly after the reshaping of the can body 16. It is to be understood that prior to the separation of the mold halves 35, and the downward movement of the plunger 19, the valve 37 will have moved to the EXHAUST position wherein the high pressure within the can body 16 will be released. The can body 16 will continue to move down with the plunger 19 until the support member 18 is seated within the mounting blocks 17. At this time, the can body 16 will be moved along the support 15 to the right, and will be replaced by another can body 16 to be reshaped.

While the can body 16 illustrated in Figures 1 to 8 is of a cylindrical configuration, it is to be understood that the can body 16 could be of a square, oval or other conventional straight side cross-section including being tapered. Also, although only one shaping of the can body 16 has been specifically illustrated methodwise, it is to be understood that the can body 16 may be reshaped to any

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one of numerous ornamental designs and that the shape illustrated in Figures 7 and 8 is for illustration purposes only, as is clearly apparent by reference to Figures 14 to 18 which will be described hereinafter.

Although in many instances the can body will be reshaped prior to the placing of an end thereon, in some instances, it may be desired to place an end, such as the end 46 of Figure 9, on the can body 16.

In order to handle a can body having an end, such as the end 46, disposed thereon, it is necessary that a slight modification be made in the supporting structure for the can body. To this end, in lieu of the support member 18, a support member 47 is shown seated in the mounting block 17 in Figure 9. The support member 47 has an internal recess 48 in the lower portion thereof in which a flange 49 projecting externally from the plunger 50 is seated. The upper end of the plunger 50 is open and a shaft 51 is disposed therein. The shaft 51 is provided with an enlarged head 52 which overlies the upper end of the plunger 51 and is seated in a recess 53 formed in the upper part of the support member 47. The upper surface of the head 52 is disposed flush with the upper surface of the support 15 to permit the can body 16 to slide thereon during the conveying of the can body 16. The shaft 51 and the head 52 are held in the upward position by means of a pin 53 which extends through a slot 54 in the plunger 50 and rests upon a suitable stop 55 disposed externally of the plunger 50 when the plunger 50 is in its lowermost position. When the plunger 50 is moved upwardly, the head 52 stays stationary while the plunger 50 and the support member 47 move upwardly with the support member 47 passing around the lower portion of the can body 16 in the area of the seam 56 between the can end 46 and the can body 16. After a slight initial upward movement of the plunger 50 and the support member 47, the head 52 will be engaged by the plunger 50 and the support member 47 to move the head 52 and the can body 16 seated thereon upwardly. The remainder of the apparatus illustrated in Figures 1 to 8 will be used in conjunction with the apparatus of Figure 9.

When no reshaping of the can end 46 is desired, the upper surface of the head 52 will be flat or will otherwise be configurated to conform to the shape of the can end 46. On the other hand, when it is desired to reshape the can end, the upper surface of the head 52 will be configurated as is indicated at 57, for example. In the event the can 16 has a second or upper end (not shown) the underside of the clamp plate 24 will be suitably configurated either to match the upper end of the can or to conform to the desired configuration to which the upper end is to be reshaped.

Reference is now made to Figures 14 and 15 wherein there is illustrated a modified form of can body, generally referred to by the numeral 60. The can body 60 has flanges 61 and 62 at the opposite end thereof for facilitating the attachment of can ends. The can body 60 was originally cylindrical prior to the reshaping thereof and may have either a welded seam or a conventional soldered seam. The can body 60 has a plurality of vertically spaced, smoothly convexly curved body portions 63 integrally connected together by narrow, more sharply curved, concavely curved body portions 64. In addition, at least the upper one of the body portions 63 has designs 65 embossed thereon, the designs 65 being shown as stars, but being variable as desired. The can body 60 will be provided with can ends, either by welding or crimping, one before filling and the other after filling.

In Figures 16 and 17, there is illustrated another example of a container which may be inexpensively formed in accordance with the invention, the container being generally referred to by the numeral 66. The container 66 is initially constantly square in cross section and has an end 67 secured to the lower end thereof while still of the square cross section. It is to be noted that the upper portion 68 of the container 66 has not been enlarged although the central portion 69 thereof has been outwardly bowed and the lower portion 70 tapers downwardly to the end 67. The upper portion 68 terminates at the upper end thereof in a flange 71 for the later attachment of a second end (not shown). Although the upper portion 68 has not been increased in cross section, the upper portion 68 has been provided with suitable decorative embossing 72.

In Figure 18, there is illustrated a modification of the container 66, the container of this Figure being referred to by the numeral 73 and having an upper portion 74 which corresponds to the upper portion 68. However, the upper portion 74 has decorations which include embossed portions 75 and debossed portions 76.

It is to be understood that the can bodies may be lithographed or otherwise decorated prior to the explosion reshaping thereof, it being possible to accurately determine the stretching of the various portions of the can bodies or like containers and to predecorate accordingly. It is also to be understood that while the invention has been specifically described with respect to cans, the invention will equally as well apply to numerous metal objects of varying sizes including commercial drums, pails, wastepaper baskets, etc.

The invention may also be practiced with plastic containers and like objects. At the present time the commercially accepted way of forming plastic articles is to extrude a

thick walled tube of small diameter and to blow the tube in a mold. This process is a slow one and there is an undue thinning of the plastic at areas of maximum stretching. Further, if the plastic container is to be provided with metal ends, the ends of the plastic container must be trimmed after the molding thereof. By utilizing the method of this invention, it is proposed to explosively reshape extruded thin wall plastic tubing. This can be quickly and inexpensively accomplished while holding the thinning of the plastic material to a minimum. The extruded tubing may be of any desired cross section. When the plastic container is to be provided with metal ends, the ends are applied prior to the explosive reshaping of the plastic, thereby eliminating the normal trimming of the ends of the plastic member.

The primary test conducted with respect to this matter has utilized a mixture of city gas and air. The city gas utilized was of approximately 1,000 B.Th.U. per cubic foot heat content, and from an economical standpoint, in many instances, this particular gas mixture may prove the most economically feasible. On the other hand, as is clearly indicated by the graphs, a much greater effect may be obtained utilizing a mixture of acetylene and oxygen. The graphs show the results obtainable with the various hydro-carbons mixed with either oxygen or air, as well as a combustible mixture of hydrogen and either oxygen or air. A hydrogen oxygen or air mixture provides a very cleanly burning fuel and may be a desirable mixture, although the maximum available explosive pressure utilizing hydrocarbon is not as great as that obtainable with the hydro-carbons tested. On the other hand, as is clearly indicated in the graphs of Figures 12 and 13, hydrogen produces a very high maximum rate of pressure rise and is second as compared with acetylene of the gases tested. It was found during testing that the deformation of the can body was not dependent primarily on the maximum available pressure as a result of the explosion, but upon the pressure shock wave, and this is borne out by a comparison of the graphs of Figures 10 and 12, for example. The results obtainable with hydrogen were very good, although the maximum available explosive pressure utilizing hydrogen was much lower than that available with the tested hydrocarbons.

Although some gas mixtures may produce much better results than others for complicated reshaping of can bodies, where the reshaping is relatively mild, it will of course, be economically feasible to utilize gas mixtures which produce much less pressures and have lower rates of pressure rise in that these will not be necessary and will not require the more expensive gases.

The ability to deform and reshape a container on an economically feasible basis is a great advance in the container manufacturing art in that it now permits a manufacturer of containers to provide economically containers which have ornamental configurations comparable with the ornamental configurations of containers formed of glass and conventionally molded plastic. At the same time, the comparable cost of the ornamental containers with respect to conventionally molded plastic and glass containers will be much less, so that the packaging industry may now have available inexpensive decorated containers as compared with the relatively expensive glass and conventionally molded plastic containers.

WHAT WE CLAIM IS:—

1. A method of reshaping a tubular body wherein the body is enclosed within a shaped mould and its ends are sealed and wherein combustible and combustion supporting gases are introduced into the interior of the body to form an explosive gas mixture therewithin and the mixture is ignited and exploded to produce a gaseous pressure shock wave within the tubular body which outwardly expands the tubular body into conformity with the shape of the mould.

2. A method as claimed in claim 1 in which the explosive gas mixture in the body is at a pressure in excess of atmospheric pressure but insufficient to shape the body before the mixture is ignited.

3. A method as claimed in claim 1 or 2 wherein the products of combustion are exhausted from the reshaped body before the reshaped body is removed from the mould.

4. A method as claimed in claim 1, 2 or 3 in which the combustible gas is first introduced into the interior of the body followed by the combustion supporting gas to form the explosive gas mixture.

5. A method as claimed in any of claims 1 to 4 in which air is exhausted from within the body prior to the introduction of the gases.

6. A method as claimed in any of claims 1 to 5 in which the combustible gas is hydrogen.

7. A method as claimed in any of claims 1 to 5 in which the combustible gas is a hydro-carbon.

8. A method as claimed in any of claims 1 to 7 in which the combustion supporting gas is substantially pure oxygen.

9. A method as claimed in any of claims 1 to 7 in which the combustion supporting gas is air.

10. A method as claimed in any preceding claim in which a decorative coating is applied to said tubular body prior to the reshaping thereof.

11. A method as claimed in any preceding claim in which an end closure is secured to one end of the tubular body prior to enclosing it in the mould.

12. A method as claimed in claim 11 in which the end closure is also explosively reshaped.

13. A method as claimed in claim 11 or 12 wherein said tubular body with said end closure is a can body.

14. A method as claimed in any of claims 1 to 10 wherein end closures are secured to the ends of the reshaped tubular body.

15. A method as claimed in any of claims 1 to 10 wherein the tubular body is an extruded body.

16. A method as claimed in claim 15 in which the tubular body is an extruded thin walled plastic polymeric tube and a metal end closure is applied to at least one end of the tube prior to placing the tube in the mould.

17. A method of reshaping a tubular body substantially as hereinbefore described with reference to the accompanying drawings.

18. A tubular body reshaped by the method as claimed in any preceding claim.

19. Apparatus for reshaping tubular bodies comprising a support member, a clamp plate member cooperable with said support for clamping a tubular body to be reshaped therebetween with the ends thereof sealed, a split mould co-operating with said support and said clamp plate for enclosing the tubular body, a gas line connected to one of said members, a valve connected to said gas line, other lines connected to said valve for selective communication with said gas line by said valve for the introduction of combustible and combustion supporting gases into the interior of the tubular body to form an explosive gaseous mixture therein and an ignition device carried by one of said members for igniting and exploding said gaseous mixture.

20. Apparatus as claimed in claim 19 in which said other lines include an exhaust line, a combustible gas supply line, and a combustion supporting gas supply line.

21. Apparatus as claimed in claim 19 or 20 in which said other lines also include a vacuum line.

22. Apparatus as claimed in claim 19, 20 or 21 having means for energizing said ignition device in timed relation to the operation of said valve.

23. Apparatus as claimed in any of claims 19 to 22 in which said support member is configurated for the simultaneous explosive reshaping of an end closure of the tubular body closing one end thereof.

24. Apparatus for reshaping tubular bodies constructed and adapted to operate substantially as hereinbefore described with reference to and as illustrated in Figs. 1 to 8, or as modified by Fig. 9, of the accompanying drawings.

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FIG. 1

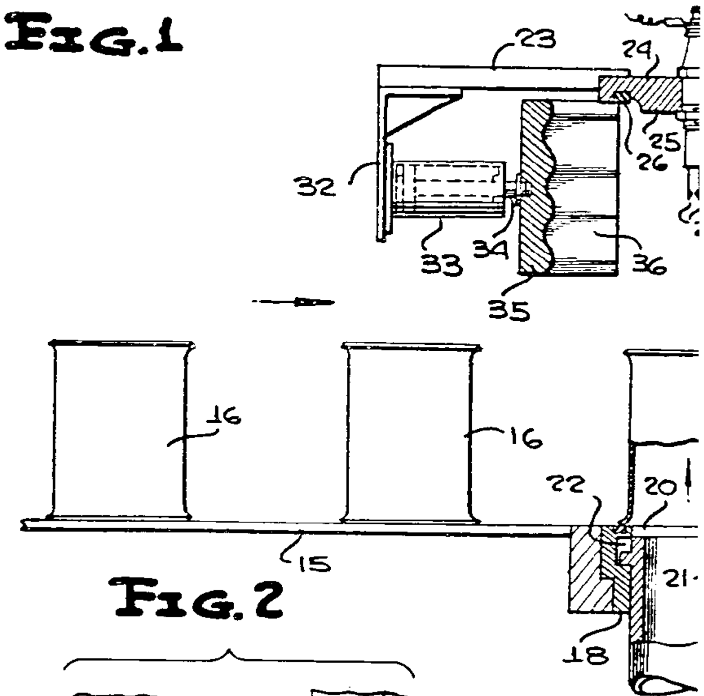
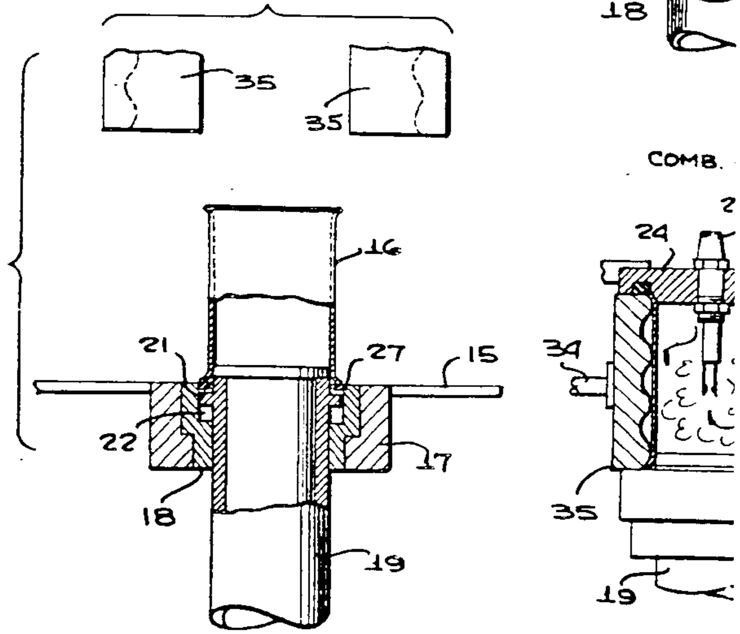


FIG. 2



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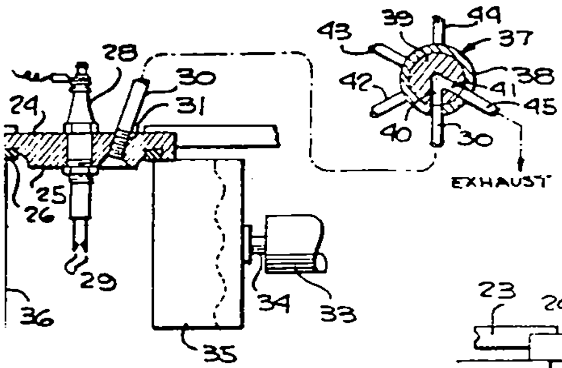
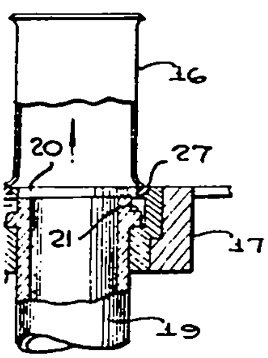




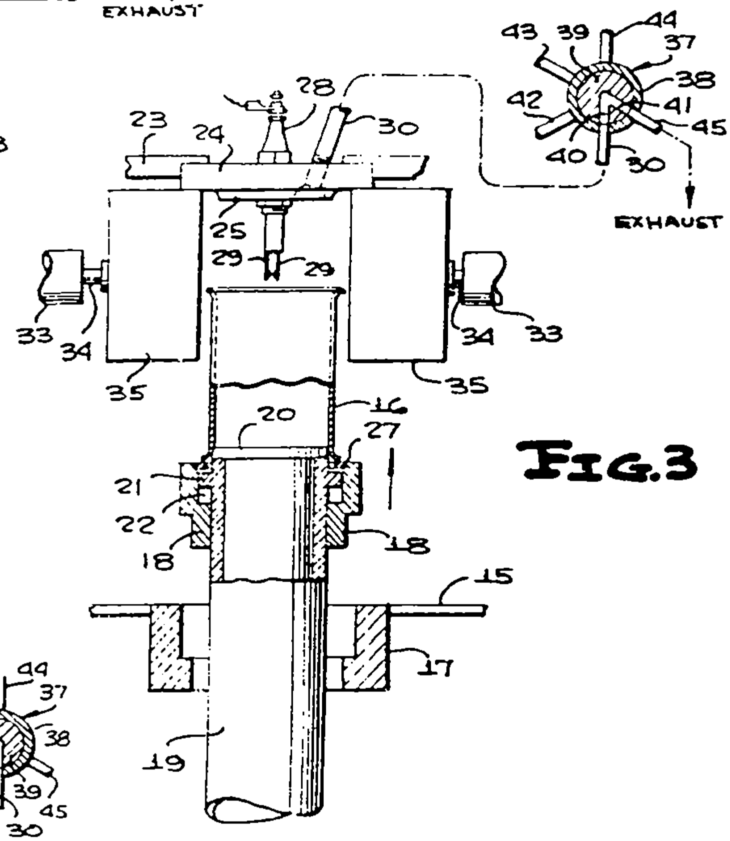


FIG.3

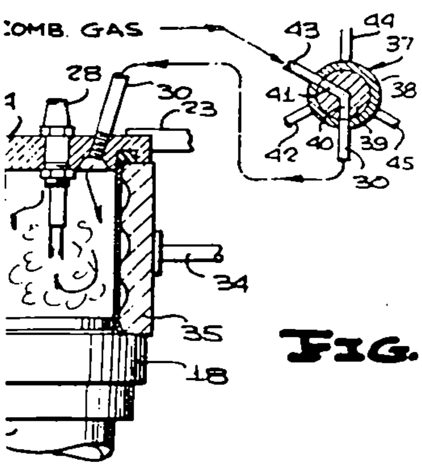
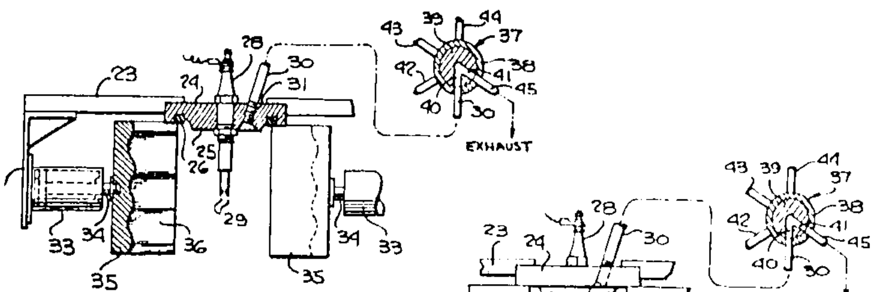
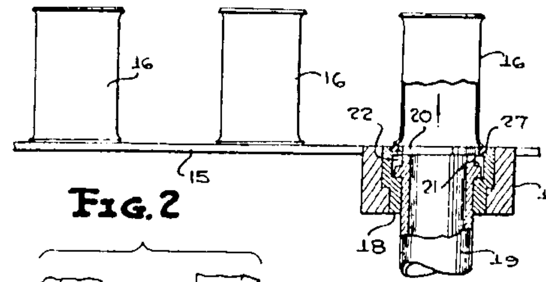


FIG.5

FIG. 1





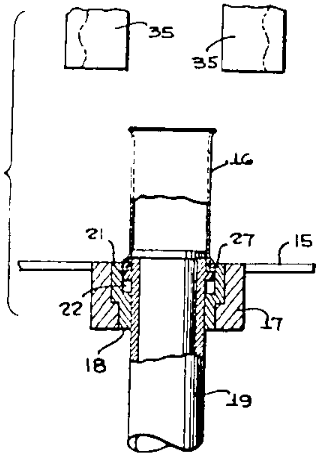


FIG. 2

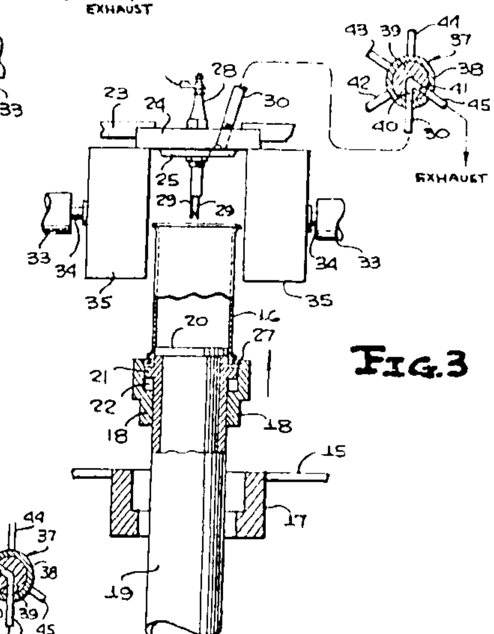


FIG. 3

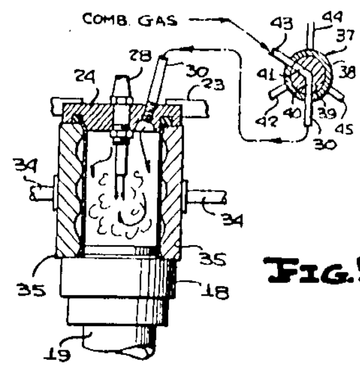


FIG. 5

FIG.4

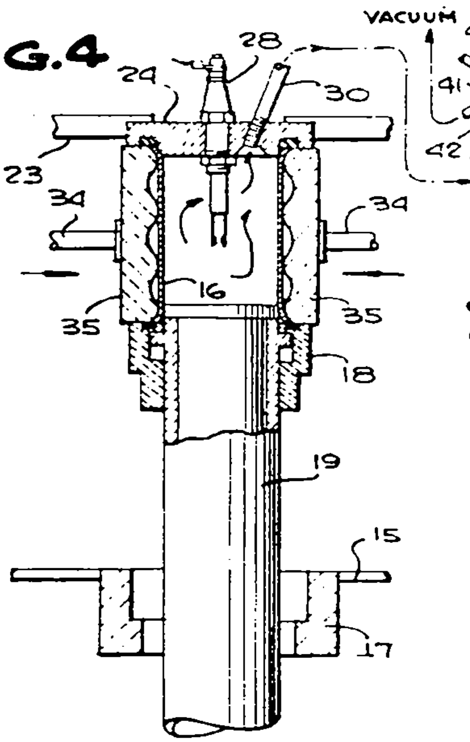


FIG.

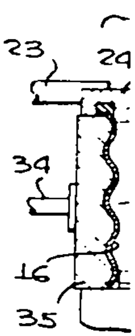
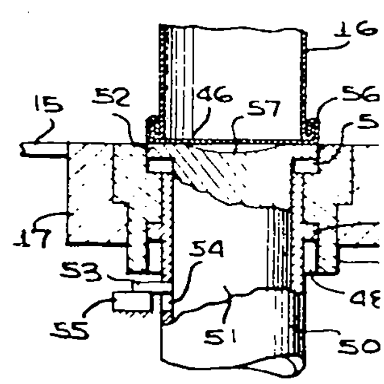


FIG.9

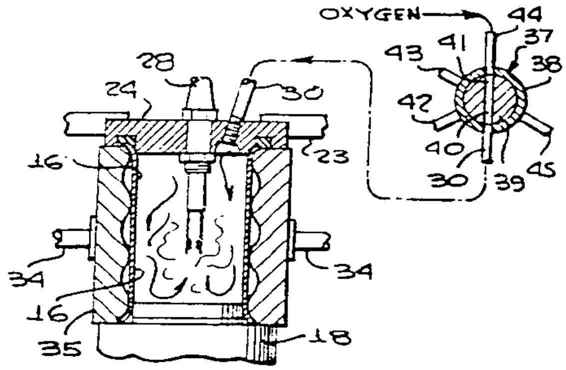


1026056 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

FIG. 6



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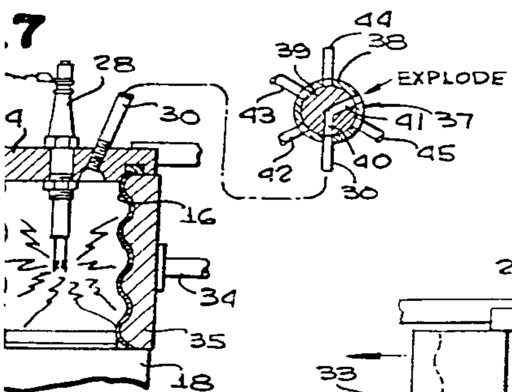


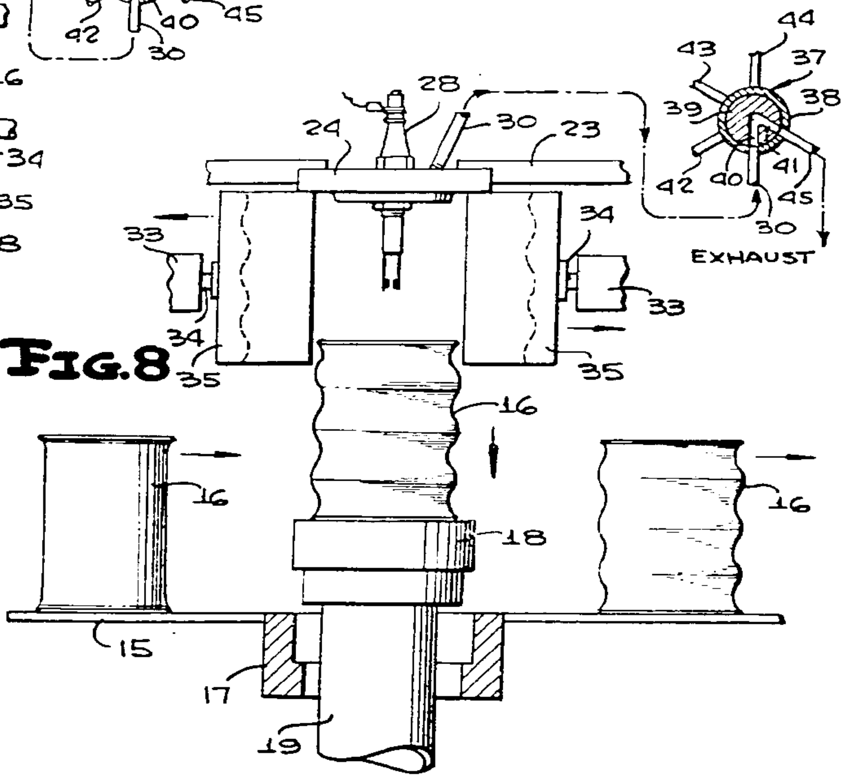


FIG. 8

1026056 COMPLETE SPECIFICATION

5 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 2

FIG. 4

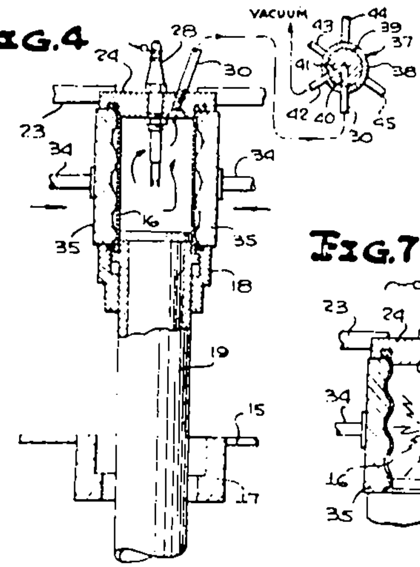


FIG. 7

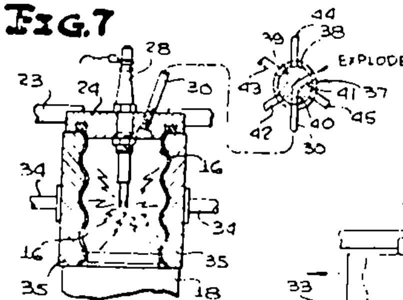


FIG. 6

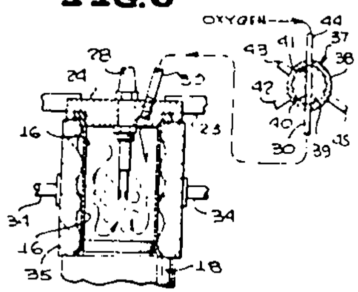


FIG. 9

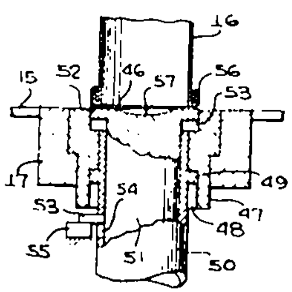
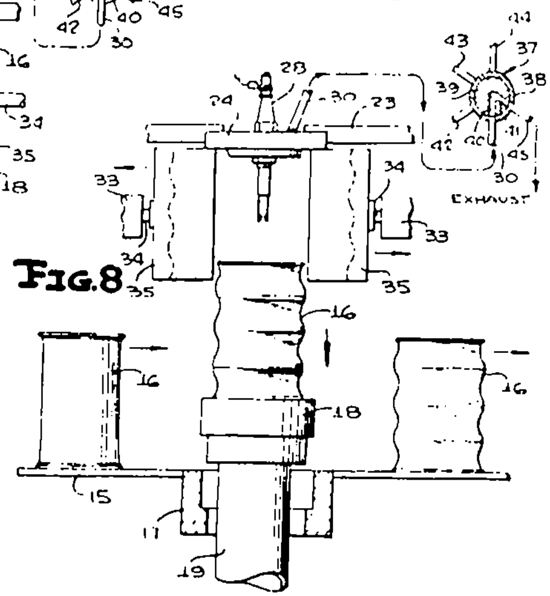


FIG. 8



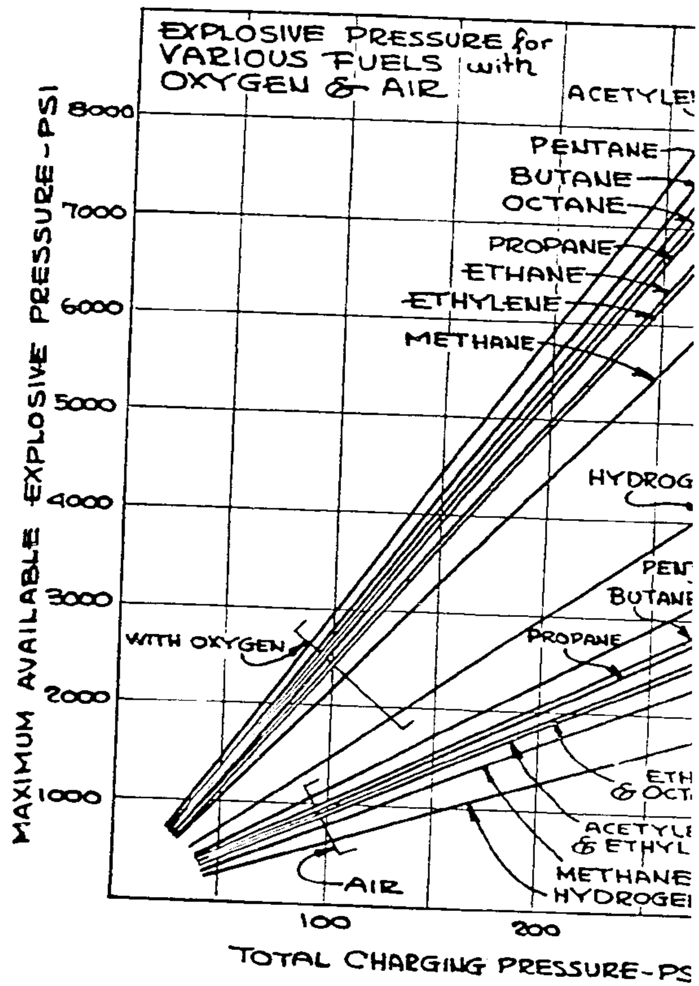

EXPLOSIVE PRESSURE for VARIOUS FUELS with OXYGEN & AIR
MAXIMUM AVAILABLE EXPLOSIVE PRESSURE - PSI
8000
7000
6000
5000
4000
3000
2000
1000
PENTANE
BUTANE
OCTANE
PROPANE
ETHANE
ETHYLENE
METHANE
WITH OXYGEN
PROPANE
AIR
METHANE
100
200
TOTAL CHARGING PRESSURE-PS

FIG. 10

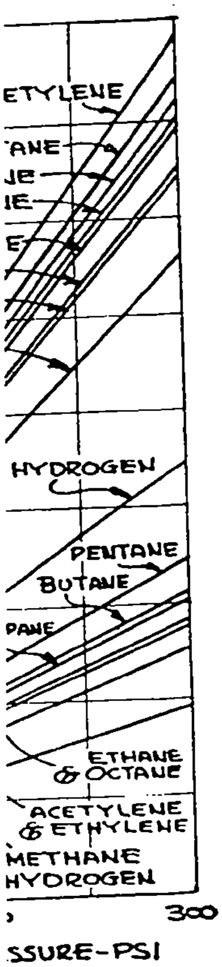
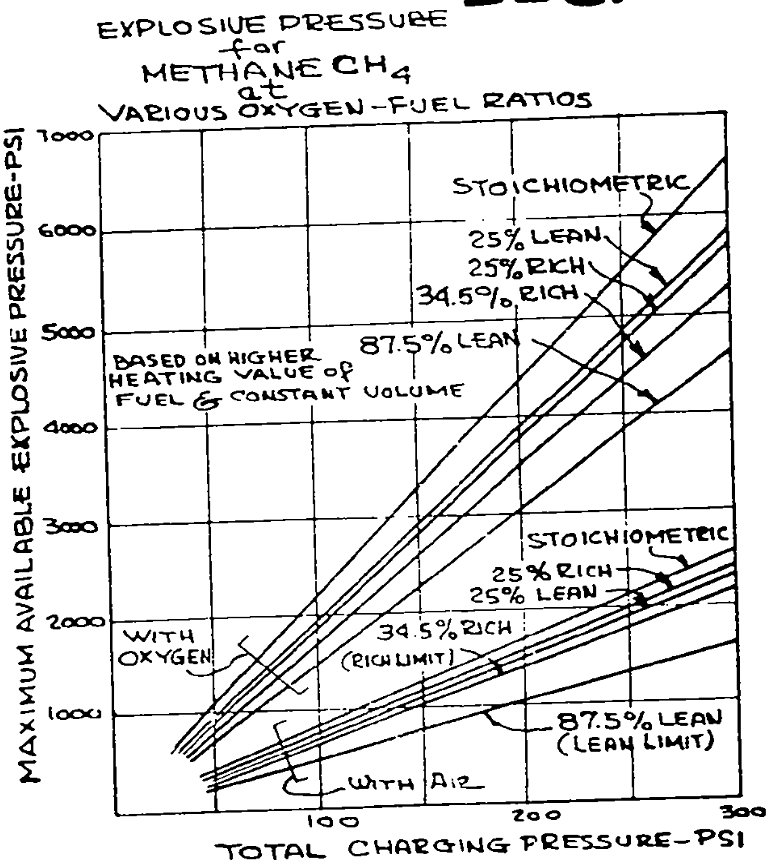

ETYLENE
ANE
HYDROGEN
PENTANE
BUTANE
PANE
ETHANE
& OCTANE
ACETYLENE
& ETHYLENE
METHANE
HYDROGEN
300
SSURE-PSI

FIG. 11


EXPLOSIVE PRESSURE
for
METHANE CH_4
at
VARIOUS OXYGEN-FUEL RATIOS
MAXIMUM AVAILABLE EXPLOSIVE PRESSURE-PSI
7000
6000
5000
4000
3000
2000
1000
STOICHIOMETRIC
25% LEAN
25% RICH
34.5% RICH
87.5% LEAN
BASED ON HIGHER HEATING VALUE of FUEL & CONSTANT VOLUME
WITH OXYGEN
STOICHIOMETRIC
25% RICH
25% LEAN
34.5% RICH
(RICH LIMIT)
87.5% LEAN
(LEAN LIMIT)
WITH AIR
100
200
300
TOTAL CHARGING PRESSURE-PSI

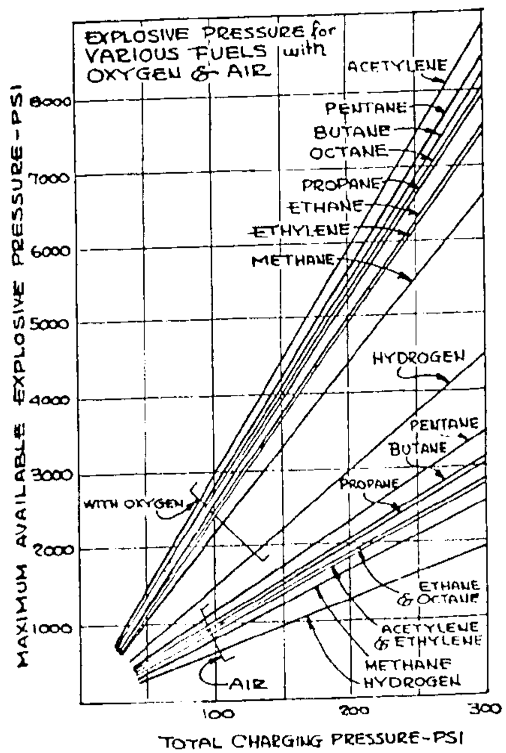
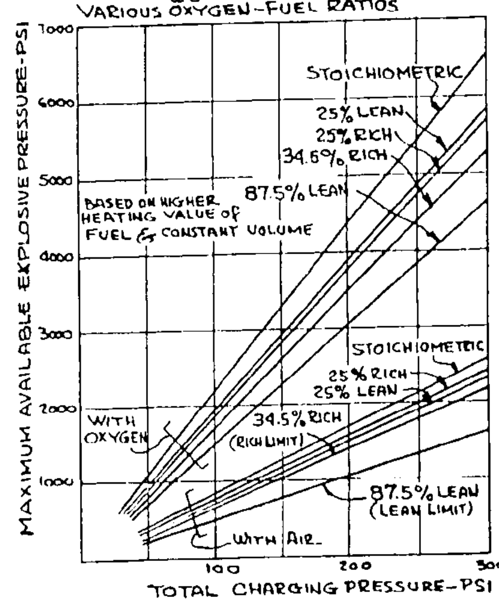
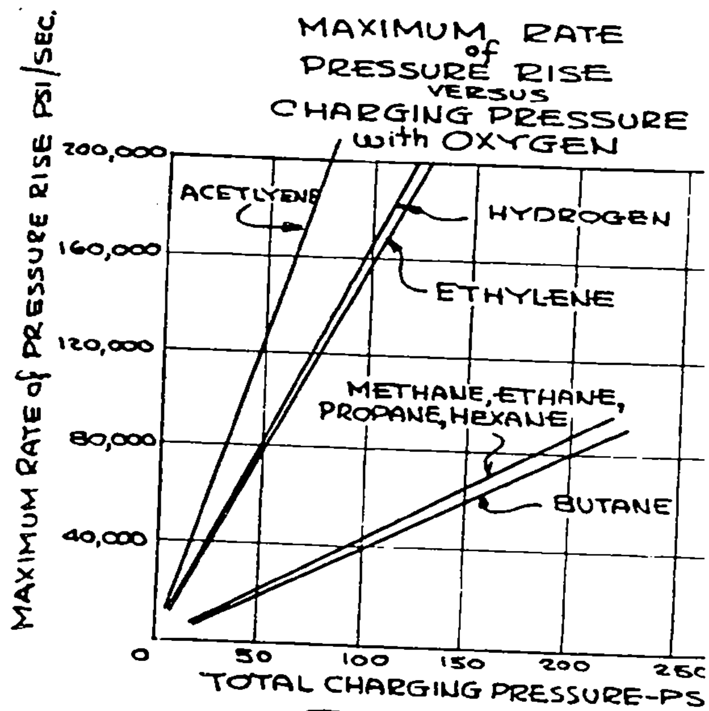

EXPLOSIVE PRESSURE for VARIOUS FUELS with OXYGEN & AIR
MAXIMUM AVAILABLE EXPLOSIVE PRESSURE-PSI
TOTAL CHARGING PRESSURE-PSI
8000
7000
6000
5000
4000
3000
2000
1000
100
200
300
ACETYLENE
PENTANE
BUTANE
OCTANE
PROPANE
ETHANE
ETHYLENE
METHANE
HYDROGEN
WITH OXYGEN
PENTANE
BUTANE
PROPANE
ETHANE & OCTANE
ACETYLENE & ETHYLENE
METHANE
HYDROGEN
AIR

FIG.10

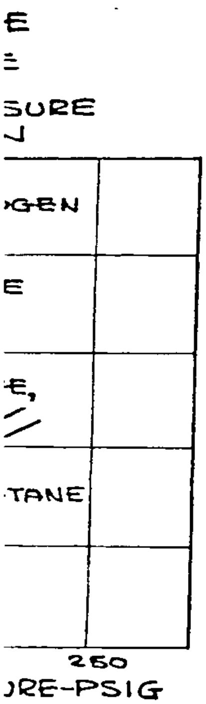
FIG.11


EXPLOSIVE PRESSURE for METHANE CH4 at VARIOUS OXYGEN-FUEL RATIOS
MAXIMUM AVAILABLE EXPLOSIVE PRESSURE-PSI
TOTAL CHARGING PRESSURE-PSI
7000
6000
5000
4000
3000
2000
1000
100
200
300
STOICHIOMETRIC
25% LEAN
25% RICH
34.5% RICH
87.5% LEAN
BASED ON HIGHER HEATING VALUE of FUEL & CONSTANT VOLUME
WITH OXYGEN
STOICHIOMETRIC
25% RICH
25% LEAN
34.5% RICH (RICH LIMIT)
87.5% LEAN (LEAN LIMIT)
WITH AIR



MAXIMUM RATE of PRESSURE RISE VERSUS CHARGING PRESSURE with OXYGEN
MAXIMUM RATE of PRESSURE RISE PSI/SEC.
200,000
160,000
120,000
80,000
40,000
0
50
100
150
200
250
TOTAL CHARGING PRESSURE-PSI
ACETLYENE
HYDROGEN
ETHYLENE
METHANE, ETHANE, PROPANE, HEXANE
BUTANE

FIG. 12



MAXIMUM RATE
of
PRESSURE RISE
VERSUS
CHARGING PRESSURE
(IN AIR)

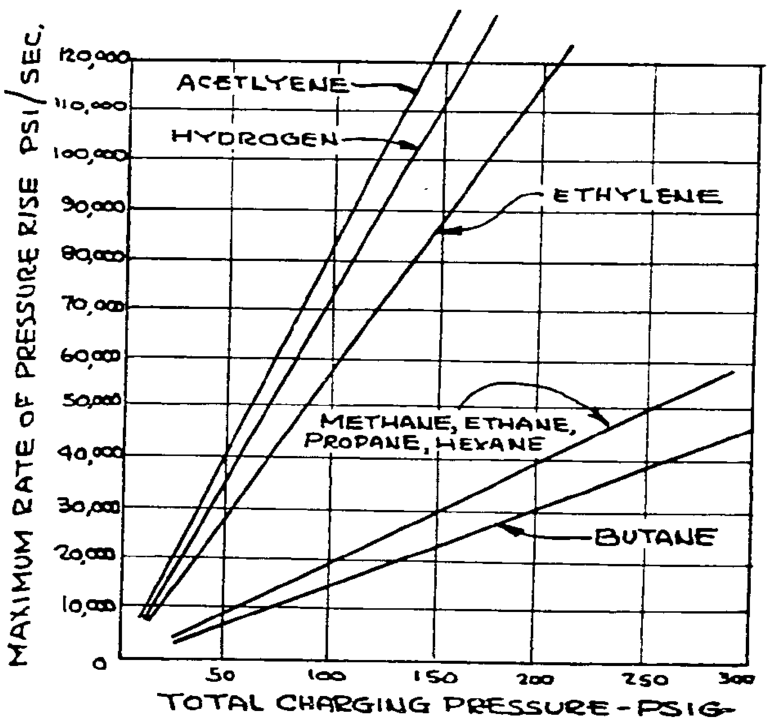


FIG. 13

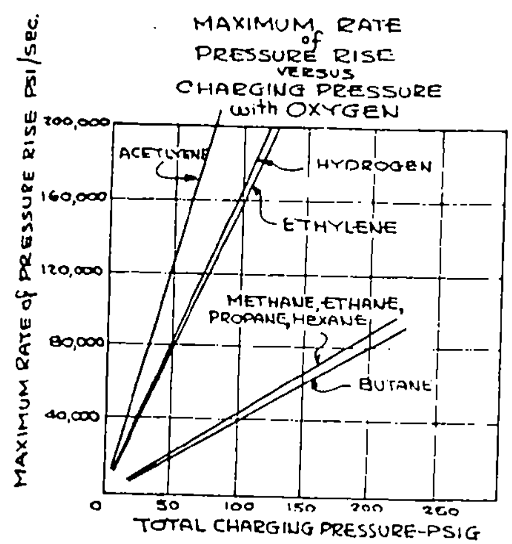

MAXIMUM RATE of PRESSURE RISE VERSUS CHARGING PRESSURE with OXYGEN
MAXIMUM RATE of PRESSURE RISE PSI/SEC.
200,000
160,000
120,000
80,000
40,000
0
50
100
150
200
250
TOTAL CHARGING PRESSURE-PSIG
ACETLYENE
HYDROGEN
ETHYLENE
METHANE, ETHANE, PROPANE, HEXANE
BUTANE

FIG. 12

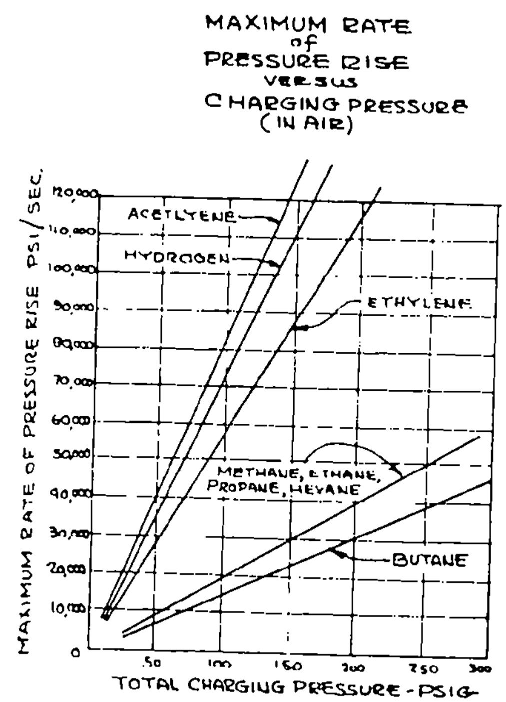

MAXIMUM RATE of PRESSURE RISE VERSUS CHARGING PRESSURE (IN AIR)
MAXIMUM RATE OF PRESSURE RISE PSI/SEC.
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
50
100
150
200
250
300
TOTAL CHARGING PRESSURE - PSIG
ACETLYENE
HYDROGEN
ETHYLENE
METHANE, ETHANE, PROPANE, HEXANE
BUTANE

FIG. 13

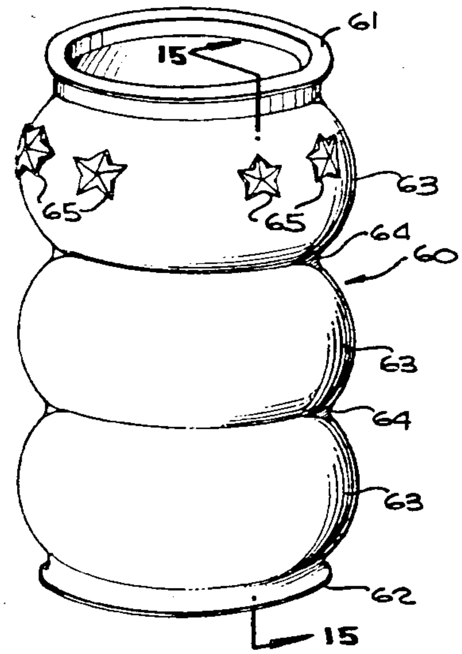
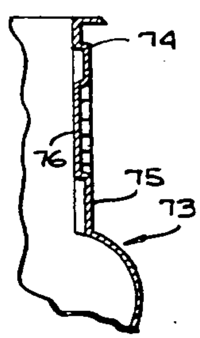


FIG. 14

FIG. 18

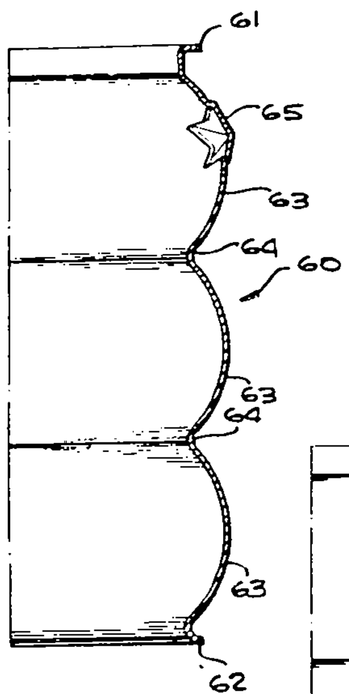


1026056 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 5

FIG.15



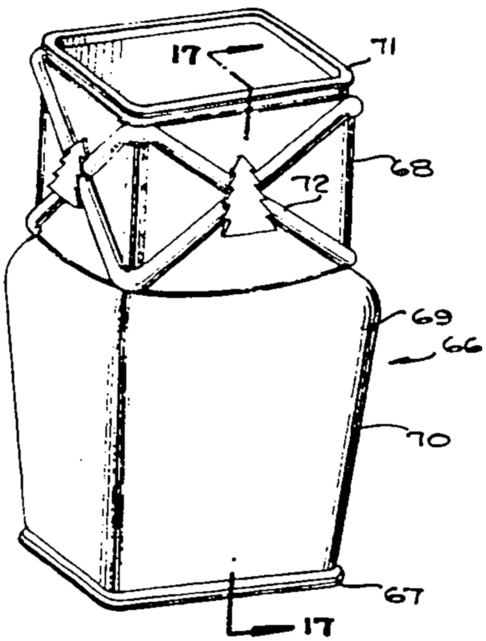


FIG.16

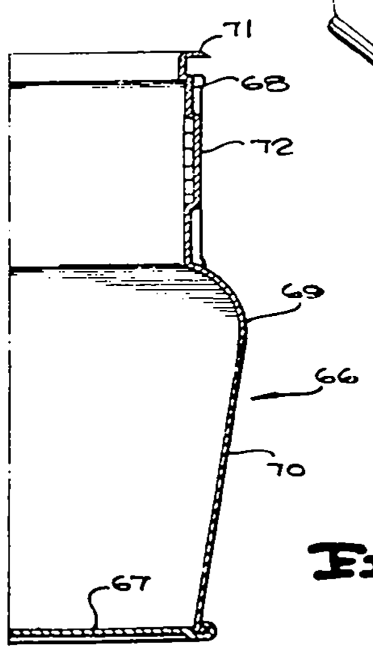
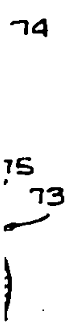


FIG.17



1026056 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 5

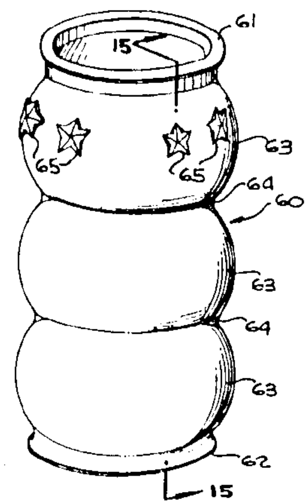
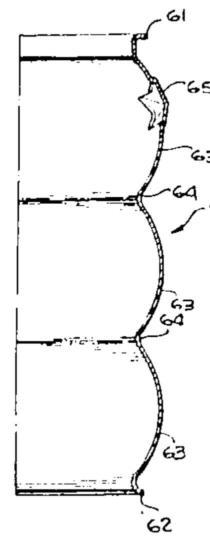


FIG.14

FIG.15



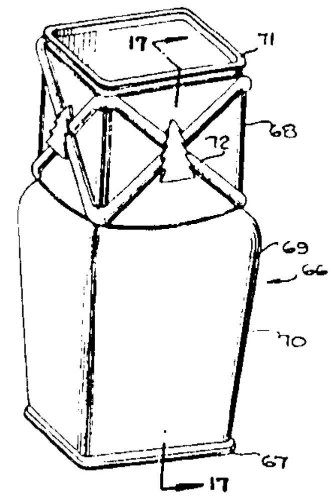
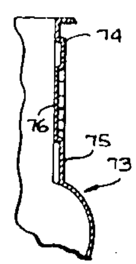


FIG.16

FIG.18



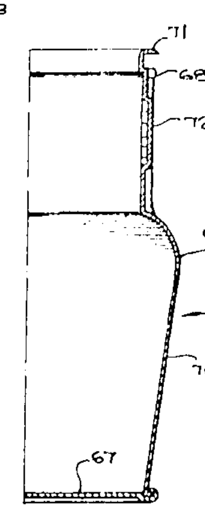


FIG.17